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The integrity of the syllable in developmental apraxia of speech

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Abstract

Three children with developmental apraxia of speech (DAS) identified the number of syllables in words, judged intrasyllabic sound positions, and constructed syllable shapes within monosyllabic frames. Results suggest that DAS children demonstrate an apparent breakdown in the ability to perceive ''syllableness'' and to access and compare syllable representations with regard to position and structure. Based on these findings, DAS is viewed as a disorder characterized by an impoverished phonological representation system. **Learning outcomes:** On the basis of this article, the reader will be able to (1) describe the deficits in syllabic perception demonstrated by some participants with DAS; (2) examine the utility of metalinguistic tasks in the differential diagnosis of DAS; and (3) evaluate the findings with respect to competing theoretical perspectives on DAS.
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1. Introduction

Developmental apraxia of speech (DAS) is a neurologically based disorder in the programming of articulatory movements. Primary features of the disorder include a restricted phonemic repertoire, inconsistent speech sound errors, difficulty sequencing speech movements, prosodic abnormalities, and delayed

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expressive language (Davis, Jakielski, & Marquardt, 1998; Marquardt, Sussman, & Davis, 2001). The study of DAS has been marked by controversy about the legitimacy of the diagnostic label (Guyette & Diedrich, 1981; Marquardt & Gillam, 1999); consequently, research has been directed toward identifying characteristics that may be important to its reliable identification (e.g., Davis et al., 1998; Shriberg, Aram, & Kwiatkowski, 1997; Thoonen, Maassen, Gabreels, Schreuder, & de Swart, 1997; Yoss & Darley, 1974).

The consensus view of DAS is that it is basically a disorder of speech motor control (Hall, Jordan, & Robin, 1993). This overall assessment is supported by an array of clinical and experimental evidence showing a variety of sequencing problems in DAS, whether phoneme-to-phoneme or syllable-to-syllable. Crary (1984) observed that children with DAS demonstrate deficits in syllable structure control including the processes of final consonant deletion, consonant cluster reduction, syllable deletion, and syllable reduplication. Riley (1984) noted that disruptions of syllable accuracy, rate, and sequencing are essential to the diagnosis of DAS.

Errors of production, whether they are omissions, revisions, additions, or deletions, will disrupt intrasyllabic order or structure. However, these output errors in DAS children may actually be symptomatic of a more general language deficit—the linguistic integrity of underlying phonological structures may be compromised in DAS. Attention to strictly performance-level breakdowns ignores possible etiological roots of the disorder that might be more related to competence-level language mechanisms. Ascertaining the implicit or metalinguistic abilities of DAS children, particularly their level of phonological competence, can provide a deeper understanding of how their limited language system functions. In addition, if language deficits are documented at a basic competence level, then a more parsimonious account of the disorder is at hand as many of the varied symptoms can be explained by a single overriding factor.

Our experimental and theoretical approach to DAS is to try to ascertain if linguistic bases might exist for the obvious motor programming disturbances. Admittedly, assessing the competence-level intuitions of children, especially DAS children, is a difficult undertaking. However, the distinct possibility exists that the speech motor problems exhibited in DAS could be explained by a dissolution of the neural substrates representing the phonological framework of the child's language, apart and distinct from, but certainly interacting with, speech motor programming performance (Sussman, Marquardt, & Doyle, 2000; Sussman, Marquardt, Doyle, & Knapp, 2001). Neurological scrutiny through current brain imaging techniques will not allow verification of such a speculative position. At present, only behavioral evidence can be marshaled to provide, at best, indirect support. Despite this limitation, the notion of a more basic underlying linguistic deficit in DAS is attractive as it can potentially account for the wide diversity of clinical findings when research efforts to document specific central nervous system anomalies or lesions have had limited success (Horwitz, 1984; Jernigan, Hesselink, Sowell, & Tallal, 1991; Knuckey, Apsimon, & Gubbay, 1983).

Preliminary support for this position comes from a rhyming study by Marion, Sussman, and Marquardt (1993). In this study, four DAS children, aged 5–7 years old, were compared to four age-matched controls in their ability to both generate and judge rhymes in word series and forced-choice word pairs. The DAS children revealed a striking inability to recognize rhymes and to produce rhymes compared to the normal children. They concluded that speech motor programming deficits could not explain, by themselves, such phonological incompetence. A less descriptive and more explanatory account was to postulate an impoverished vowel representation system as underlying their inability to rhyme. In order to satisfactorily rhyme, the child must be able to access an ''internalized auditorily coded representation entity that matches the vowel of the input string'' (Marion et al., 1993, p. 148). The internal representation of the phoneme, i.e., the vowel, must already exist in neural form to be able to recognize a sound match or activate a rhyming output. DAS children do not appear to possess such basic phonemic representations to allow rhyming to occur. Marion et al. speculated that DAS might involve a neurological maldevelopment of substrates destined to encode both phonemic and syllabic representations. Neurological impairments involving phonological language structures, specifically preclusion of normal neurogenesis in substrates representing both phonemes and syllabic frames, would be coincident with the wide-ranging array of phonetic, phonological, prosodic, and language-level breakdowns documented in this enigmatic disorder.

The syllable is recognized as a fundamental constituent in phonological theory (Blevins, 1994). The syllable also possesses an interesting contradiction. On one hand, it has been notoriously difficult to formally and unambiguously define the syllable (Bell & Hooper, 1978; Blevins, 1994), while informally, it appears to be the linguistic unit that speakers, including children, most easily and intuitively sense. Formal phonological analyses, including studies of phonotactic constraints, suprasegmentals, reduplication and deletion, have found that the domain of operation is more closely tied to the syllable than to any other unit of sound structure (Beckman, 1986; Broselow, 1979; Fudge, 1969; Hayes, 1991; Hooper, 1972, 1976; Moskowitz, 1970, 1971). Of most relevance, however, to our view of the syllable, vis-a-vis the phonological dissolution in DAS, is the clear intuition native speakers possess about the syllable. For example, White (1955) described a language game where /–ti/ is suffixed to each syllable of the word. Laycock (1972), in his survey of language games, described at least 20 in which the target of sound manipulation is the syllable. Sherzer (1976, 1982) has reported studies of language play in Cuna and Balinese where the operations of the play language are strictly based on the syllable structure of the language. Similarly, Liberman, Shankweiler, Fischer, and Carter (1974), using a tapping task, showed that young children, from nursery through first grade, were more adept at recognizing syllable structure/segmentation compared to phonemes. We interpret these common observations as support for the idea that a speaker's intuitions can indirectly reflect the mental representation of particular units of phonological structure.

In this case study-based investigation, we explored the construct of the syllable in DAS, not from an output, or performance, perspective, but from a metalinguistic perspective. We studied the ability of three DAS children to identify the number of syllables in words, to judge intrasyllabic sound positions, and to construct syllable shapes within monosyllabic frames. The question of interest is whether or not DAS children exhibit a metalinguistic awareness of the syllable appropriate for their age.

2. Method

2.1. Participants

Six children between 6 and 8 years of age participated in the study. The three DAS participants demonstrated symptoms consistent with identification of the disorder including a reduced phonemic repertoire, difficulty in syllable sequencing, inconsistent speech errors, expressive language delay, and prosodic deficits (Marquardt et al., 2001). DAS participants had been receiving treatment for a minimum of 3 years at the time of the study. They were matched with three children with normal speech and language development on the basis of gender and age (within 6 months) (Table 1). No attempt was made to match participants on the basis of receptive language performance because of the potential for selection of participants atypical of either group (Nippold, 1992). The normal participants were included not to develop a referential scaffolding for comparison with the DAS participants, but to validate previous findings that children within this age range are expected to complete metalinguistic tasks focused on syllables without difficulty (Bird, Bishop, & Freeman, 1995; Fox & Routh, 1975; Kamhi, Lee, & Nelson, 1985).

Participants demonstrated auditory acuity within normal limits bilaterally based on pure tone audiometric screening at octave frequencies from 250 to 4000 Hz; no obvious signs of structural abnormalities or dysarthria from oral peripheral examination of the speech mechanism; and no positive history for emotional disorders or fluctuations in auditory acuity due to middle ear disorders.

Participants were administered a battery of speech and language tests including the Screening Test for Developmental Apraxia of Speech (Blakeley, 1980), the Test of Auditory Comprehension of Language (TACL-R) (Carrow-Woolfolk, 1985), the Peabody Picture Vocabulary Test–Revised (PPVT-R) (Dunn & Dunn, 1981), and the Templin–Darley Screening Test of Articulation (TD) (Templin & Darley, 1969). A3 received the Goldman–Fristoe Test of Articulation (GFTA) (Goldman & Fristoe, 1986) in place of the Templin–Darley. Receptive language measures were included to establish absence of language disorder, an exclusionary criterion for diagnosis of DAS. Measures of nonlinguistic abilities were obtained from client records for the DAS participants when available to ensure cognitive and perceptual abilities within normal limits. In addition, a speech

Table 1
Participant data

Participant	Gender	Chronological age	PPVT-R		TACL-R		Templin–Darley percentile score	Screening test for DAS		Hearing	Speech intelligibility	Motor speech examination
			Percentile rank	Age equivalent	Percentile rank	Age equivalent		Total weighted score	Probability of apraxia (%)			
A1	F	7–8	9	6–0	29	7–3 to 7–9	2	−767	>99	WNL	Severely unintelligible	Full range of movements; difficulty imitating syllable sequences
A2	M	6–8	8	5–2	34	5–11 to 6–3	18	−369	>99	WNL	Moderately unintelligible	Full range of movements; difficulty imitating syllable sequences
A3[a]	M	7–7	77	9–8	32	8–1 to 9–0	b	−237	>99	WNL	Intelligible	Difficulty putting tongue behind upper teeth, imitating syllable sequences
N1	F	8–0	72	9–1	45	8–7 to 9–11	50	+196	<1	WNL	Intelligible	Normal
N2	M	6–3	92	8–0	80	7–8 to 8–4	50	+195	<1	WNL	Intelligible	Normal
N3	M	8–0	66	8–5	86	10–0+	50	+173	<1	WNL	Intelligible	Normal

[a]A3's scores for the PPVT-R and TACL-R were obtained at the age of 8–4; apraxia screening and motor speech examination administered at the age of 5–0.
[b]Articulation scores for A3 were obtained from the GFTA, with a percentile rank of 16.

Table 2
Phonetic inventories for the DAS participants

Participant	I	M	F	Vowels	Blends
A1	m, b, p, n, t, g, h	b, p, w, z	m, k	æ, ou, u, a, ʌ, ɛ	–
A2	b, p, t, n, s, z, f, g, h, w	b, p, t, s	p, t, k, z, m, v, n	i, ɪ, ʊ, æ, o, u, ʌ, ɛ	bl, pl, kw
A3	m, b, p, n, s, f, θ, k, tʃ, l, j, r, dʒ, g	m, b, d, t, n, s, g, k, ŋ, l, p, tʃ	m, d, t, n, s, z, g, k, ŋ, p, θ, tʃ	i, ɪ, æ, ou, a, e, ʌ, ɛ, ɔ, aɪ, aʊ	bl, tw, dw, kw, sm, fl, sbw

Phonetic inventory from production of words on the Assessment of Phonological Processes (Hodson, 1981). Phonemes were placed in inventory if produced at least one time during the test, regardless of context.

motor examination was completed to assess the ability to sequence two to four syllables (Ekelman & Aram, 1984), and the Assessment of Phonological Processes (Hodson, 1981) was administered to describe more fully the articulatory development of the DAS participants (see Table 2 for phonetic inventories).

Participant A1 (7;8) had a history of severely delayed motor and speech development and received physical therapy from 12 to 36 months of age focusing on the development of gross motor skills. A1 began receiving speech and language services at age 3 in an early childhood program where sign was the primary means of communication. At age 5, expressive vocabulary was limited to 12 words. At 7 years of age, her expressive language was markedly unintelligible. She was stimulable for 80% of phonemes produced in isolation, but vowels were frequently distorted. Various treatment approaches had been used before entry to the study including contextual facilitation (Kent, 1982), contrast therapy (Stoel-Gammon & Dunn, 1985), speech pattern remediation (Hodson, 1982), and a multiple phoneme approach (McCabe & Bradley, 1975), but it had been concluded that a combination of remediation approaches determined by the phoneme to be taught should guide treatment. Results from the PPVT-R (9%) and TACL-R (29%) suggested that her language development was within gross normal limits. Academic testing completed at the age of 7;0 yielded scores ranging from 5th to 20th percentile, with her best performance in mathematics. On the TD, she produced only 2 of 50 items correctly. Her phonetic repertoire, based on the Hodson Assessment of Phonological Processes (HAPP), included primarily stops and nasals with an incomplete vowel system. Syllable structures were consistently disrupted. She was most successful in maintaining consonant–vowel (CV) and consonant–vowel–consonant (CVC) forms, which were used in attempts to produce more complex CVCC, CCV, and CCVC syllable shapes.

Participant A2 (6;8) had a normal developmental history with the exception of speech. First words were observed at 12 months and two word combinations at 18 months. At age 36 months, speech was highly unintelligible due to the large number of errors and a program of speech therapy was instituted that continued until entry into the study. The primary therapy approach employed was speech pattern remediation to facilitate intelligibility. The goals of treatment were to

reduce the occurrence of prevocalic and postvocalic cluster reduction, stridency deviations, backing, nasal deviations, and final consonant deletion. Language percentiles for the PPVT-R and TACL-R (8% and 34%, respectively) were comparable to participant A1. Administration of the Bracken Basic Concept Scale (BBCS; Bracken, 1984) at the age of 6;1 yielded a standard score of 105, indicating normal status on preacademic skills. Areas assessed included ''school readiness,'' direction/position, social/emotional, size, texture/material, quantity, and time/sequence. Performance on the TD articulation measure was 18 of 50 correct productions, suggesting a severe delay in development. The phonetic inventory was more complete than for A1 and included fricatives in addition to stops and nasals. A2 produced CV, VC, and CVC forms consistently, but exhibited a breakdown in syllable production for the more complex CCVC and CVCC forms, and did not produce any CCVC forms.

A3 (7;7) was the most intelligible of the three DAS speakers. Like participant A2, A3 had a normal developmental history with the exception of speech. At the age of 2;6, word shapes were comprised exclusively of vowels. He had been enrolled in speech therapy for approximately 5 years at the time of the study. Treatment goals focused on increasing the accuracy of consonants and vowels that were absent or frequently incorrect, and increasing the use of consonants within clusters. A3 presented with a more complete phonetic inventory than A1 or A2, producing nasals, stops, fricatives, and affricates. A variety of open and closed syllable shapes were produced, including complex forms containing consonant blends. Despite his frequent production of complex syllable types, target sounds were not consistently matched in production of complex syllables. In a diagnostic evaluation completed at 8;4, A3's spontaneous speech was largely intelligible to unfamiliar listeners (i.e., 98% intelligible) although deficits were present in production of consonant and vowel singletons as well as in complexity of word shapes. Articulation in single words was assessed by the GFTA (Goldman & Fristoe, 1986), with a percentile rank of 16, suggesting low average to borderline average articulation skills compared to other children his age. While A3's percentile rank for the PPVT-R was appreciably higher than that of A1 and A2 (77th percentile), the percentile rank for the TACL-R was comparable (32nd percentile). A variety of phonological errors was observed in spontaneous speech, including stopping, final consonant deletion, fronting of velars, cluster reduction, and gliding of liquids. Standard scores and percentiles for nonlinguistic measures were not available from A3's clinical record; however, raw scores from administration of the BBCS (Bracken, 1984) prior to enrollment in elementary school were available to present a more complete profile of the participant. Raw scores are notated as number correct out of possible correct responses. Areas assessed included direction/position (52/55), social/emotional (24/29), size (11/16), texture/material (23/24), quantity (33/38), time/sequence (32/35), and school readiness (55/61). A3's performance on school readiness tasks revealed no errors on questions of color, identification, and numbers/counting. He answered six of seven comparison items correctly and 15 of 20 shape questions correctly.

The normal participants produced the 50 items of the TD articulation measure correctly and demonstrated age-appropriate speech and language development. Weighted scores from the Screening Test for Developmental Apraxia of Speech (Blakeley, 1980), a battery that includes subtests to assess speech sound production, sequencing, and prosody, were used to confirm assignment of the participants to the groups. Based on the scores, the probability of correct assignment of the DAS participants to a DAS diagnostic category was greater than 99%; the probability of incorrect assignment of the normal participants to a DAS diagnostic category was less than 1%.

2.2. Stimuli and procedures

Each participant was administered tasks to assess the ability to: (1) detect syllables, (2) judge intrasyllabic position, and (3) judge intrasyllabic structure.

2.2.1. Task I: syllable awareness

The purpose of this task was to assess the participant's ability to detect syllables. A randomized list of 40 one- to four-syllable words (10 each of one, two, three, and four syllables) was constructed (see Appendix A). Seated across a table from the examiner, the participant was informed that words were made up of syllables or "chunks" and was instructed to tap on the table to indicate the number of syllables that were included in eight screening items (two words at each of four syllable lengths). The training items were preceded by two demonstration items. Criterion for the task was four of eight correct responses on the screening items. If the criterion level of performance was achieved, the participant was administered the 40 test items.

2.2.2. Task II: intrasyllabic position

The purpose of this task was to assess the ability to judge intrasyllabic sound positions, independent of the specific phoneme occupying a syllable position, through the manipulation of prevocalic, vocalic, and postvocalic "slot" positions in monosyllabic CVC word pairs. In this task, CVC words were related to analogs consisting of colored blocks (red, white, and black). The participant was shown three blocks arranged in a horizontal fashion and informed that the red block represented the first sound of a word, the white block the middle sound, and the black block the final or last sound. The examiner orally presented word pairs containing identical phonemes in two sound positions and a dissimilar phoneme in one sound position—initial, medial, or final (e.g. "pan"–"can"). The participant was instructed to listen carefully to the two words and to indicate where the "different" sound was in the word as represented by the blocks. Following demonstration on one item, six screening stimuli were administered; criterion was three of six correct responses. The experimental task was comprised of 30 word pairs (10 pairs for each vocalic position) presented in randomized order.

2.2.3. Task III: intrasyllabic structure

This task assessed the ability of each participant to judge single versus consonant cluster arrangements within monosyllable frames. Horizontally arranged blocks, with black blocks representing the consonant sounds and the white block the vowel sound, were used to quantify the response of each participant. The participant was informed that he/she would be solving ''puzzles'' using blocks. They were instructed that the white block represented the vowel sound and it could occur at the beginning, middle, or end of a word. The black blocks represented the consonant sounds in the word and could occur in front of, behind, or on both sides of the vowel sound. The participant was instructed to listen to the word presented by the examiner and arrange the blocks according to the sounds in the word. For each word presented, the examiner provided the participant with the vowel sound represented by the white block. For example, in the word ''blue'' the examiner placed the white block on the table and indicated that it represented the sound /u/. The examiner then supplied the child with two black blocks and instructed the child to ''make'' the word. The participant was required to decide how the black blocks should be arranged with respect to the white block (vowel sound). Following the demonstration item, 16 words were presented as a screening task; criterion was 5 of 16 correct responses. The experimental task included 56 monosyllabic words; eight words for each of seven syllable structures (CV, VC, CVC, CCVC, CVCC, CCV, and CCCVC).

2.3. Data analysis

Task I (syllable awareness) was scored by tabulating the number of words in which the number of syllables was tapped out correctly. For Task II (intrasyllabic position), the number of correct responses for each syllable position was calculated for each participant. The number of correct block arrangements for each syllable shape was determined for Task III (intrasyllabic structure).

3. Results

Participant scores for the syllable awareness, intrasyllabic position, and intrasyllabic structure tasks are shown in Figs. 1–3, respectively. In all tasks, a general pattern emerged showing impaired performance by DAS participants. The normal participants, included to ensure that children within the age range of the DAS participants are capable of performing the tasks, demonstrated minimal deficits on the syllable tasks. N1 made only one error, overall, in the intrasyllabic structure task. N2, the youngest participant, was 90–100% accurate on syllable awareness, 50–80% accurate on intrasyllabic position, and 13–100% on the intrasyllabic structure task, with most difficulty in complex syllable construction. N3 made no errors on any syllable task.

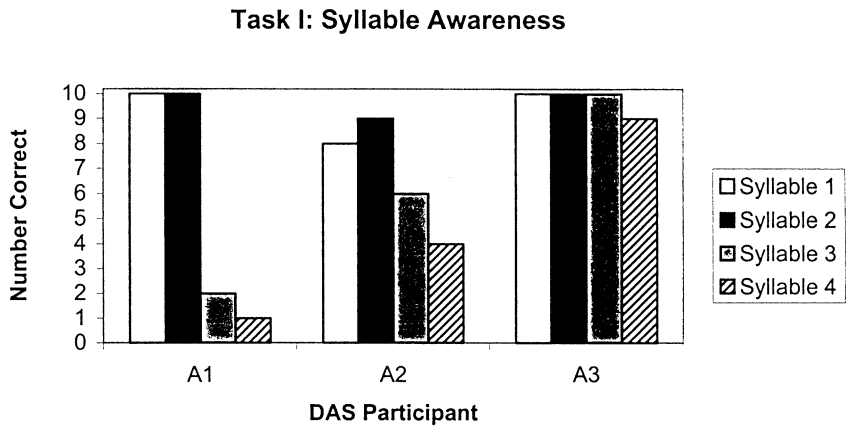

Fig. 1. Correct responses for DAS (A1–A3) participants on syllable awareness task (total possible = 10).

3.1. Participant A1

DAS participant A1 made no errors in identifying syllables in mono- and disyllable words, but showed markedly decreased performance for three- and four-syllable words (e.g., 20% and 10% accuracy, respectively). In the intrasyllabic position task, A1 had difficulty identifying the position of dissimilarity in minimal pairs regardless of where the difference occurred (e.g., prevocalic, vocalic, or postvocalic). A1 was 50% accurate for prevocalic and vocalic conditions, and 10% accurate for the postvocalic condition. In the intrasyllabic structure task, A1 constructed simple syllable shapes (e.g., CV, VC, and CVC)

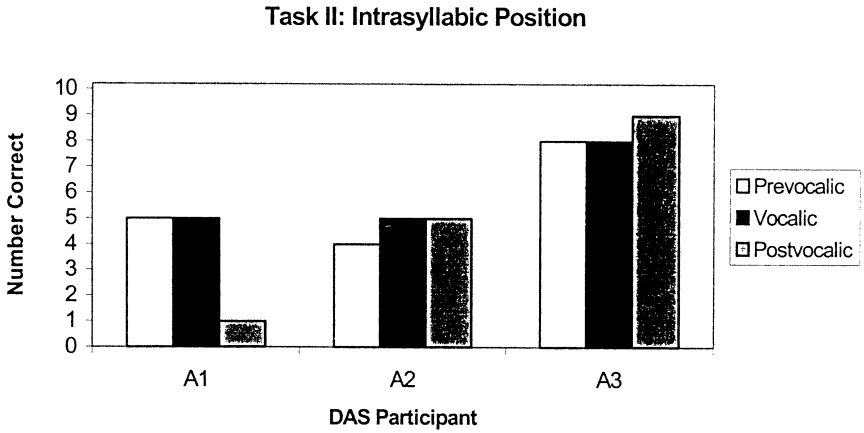

Fig. 2. Correct responses for DAS (A1–A3) participants on intrasyllabic position task (total possible = 10).

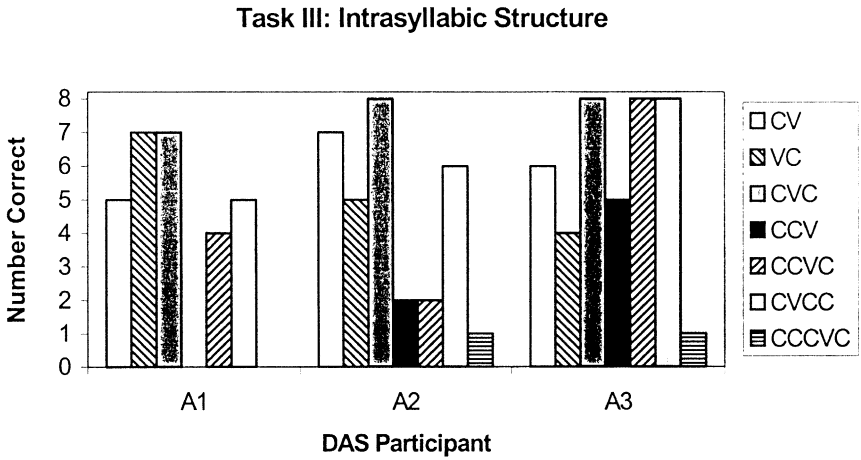

Fig. 3. Correct responses for DAS (A1–A3) participants on intrasyllabic structure task (total possible=8).

with 63–88% accuracy. Complex syllable shapes were more difficult with scores of 0% for CCV and CCCVC. She constructed CCVC and CVCC syllables with 50% and 63% accuracy, respectively.

3.2. Participant A2

Participant A2 had mixed success with the syllable awareness task, counting syllables in words with accuracy ranging from 40% to 90% (for four-syllable and two-syllable words, respectively). In the intrasyllabic position task, A2 identified the position of dissimilarity with 40% accuracy for prevocalic and 50% accuracy for both vocalic and postvocalic conditions. In the intrasyllabic structure task, A2 was fairly accurate in construction of simple shapes, with accuracy ranging from 63% to 100%. A2's ability to construct complex shapes was heterogeneous, with 75% accuracy for CVCC syllables and decreased accuracy for CCV, CCVC, and CCCVC (13%, 13%, and 25%, respectively).

3.3. Participant A3

Participant A3's performance in the syllable awareness task was comparable to the normal participants, with accuracy of 100% for counting syllables in one-, two-, and three-syllable words and 90% for four-syllable words. In the intrasyllabic position task, A3 identified the position of dissimilarity with accuracy of 80% or more for the three contexts. In the intrasyllabic structure task, A3 had mixed success in construction of simple syllables, with accuracy ranging from 50% to 100%. On complex syllables, A3 was 100% accurate for CCVC and CVCC shapes, with 63% and 13% accuracy for CCV and CCCVC. Compared to

the other apractic participants, A3 performed with greater accuracy on the syllable tasks, particularly syllable awareness and intrasyllabic position.

Results suggest that children with DAS have difficulty performing syllable tasks, including awareness of syllables, identifying the location of phonetic differences, and constructing syllable shapes. Errors in syllable counting were more evident in words with more syllables (i.e., three- and four-syllable words). Ability to locate the position of difference in minimal pairs was impaired, but was not dependent on where the difference occurred. Construction of complex syllable shapes was more difficult than for simple shapes. These difficulties, while pronounced in the two more severe DAS participants, were less apparent for the least impaired participant (A3), suggesting that performance on these tasks may be related to severity of the disorder.

In addition to severity of the disorder, treatment may potentially affect participants' performance on these tasks. For example, A3, the most intelligible speaker with the most complete phonetic inventory, had received approximately 5 years of therapy prior to the study. Focused treatment on syllable shapes as part of treatment intervention may have enhanced his ability to perform the task. Nevertheless, every apractic participant in this study demonstrated some degree of deficit relative to their age-matched peer on the syllable tasks, despite having participated in treatment for a minimum of 3 years. This suggests that deficits in syllable-level tasks persist for DAS participants even when improvements resulting from intervention are considered.

4. Discussion

The DAS participants in this study, notwithstanding the somewhat better performance of the least impaired child, demonstrated difficulty in segmenting syllables, judging intrasyllabic sound positions, and constructing single and consonant cluster arrangements. The syllable awareness task assessed the ability to detect and ''tap out'' syllables in a word and depended on the child's intuitive knowledge or recognition of what constitutes a syllable. The intrasyllabic position task required that the child access and internally compare intrasyllabic position across paired words. The intrasyllabic structure task required the child to access and internally compare representations of syllabic arrangements. Results of this study showed that children with moderate to severe DAS demonstrate an apparent breakdown in the ability to perceive ''syllableness'' and to access and compare syllable representations with regard to position and structure.

What emerges from these data is a clear indication that the linguistic underpinnings of DAS can go well beyond a simple articulatory-based motor control deficit. At a deeper level of linguistic competence, DAS children appear to demonstrate either an impoverished representational system for phonological constructs such as the syllable or the phoneme itself (Marion et al., 1993), or access to such representations. The degree of impoverishment is variable as

seen by the relatively higher level of performance of A3 compared to A1 and A2. Producing a coordinated string of consonants and vowels conforming to syllable-bound constraints presents a major obstacle to DAS children. Such a speech production situation might be analogous to playing Scrabble without a sturdy playing board (the syllabic frame) and with limited access to letters (impoverished phonemic repertoire).

Before describing further details concerning our view of the etiology of DAS, a brief discussion is needed to highlight evidence showing how (1) syllabic ''frames'' can exist independently of segmental entities, and how (2) syllabic frames directly influence on-line speech production. Studies of spoonerisms or sound exchanges provide strong support for the notion of an underlying phonological framework isomorphic to the syllable (Sussman, 1984). Speech errors, or sound exchanges, clearly show the psychological reality of the syllable, independent of segmental or phoneme elements. This realization was first promulgated by Shattuck-Hufnagel (1979, 1983) and later expanded by MacNeilage and Davis (1990, 1993) into a ''frame–content'' metaphor for speech organization and motor control. An example from speech errors will illustrate this concept. When ''cat nip'' is produced as ''naetkIp,'' the /n/ and /k/ phonemes exchange and occupy the same C1 slot in each syllable. If the speech error were the rarer ''kIt naep,'' the vowel segments /ae/ and /I/ exchange and occupy the vowel nucleus slot of each syllable. If the error were ''kaep nIt,'' the C2 slot occupies the transferred and ''migrating'' /p/ and /t/ segments. The main observation of these sound exchanges is that the segments always fill corresponding syllabic positions in each word. Moreover, consonants only exchange with consonants and vowels with vowels. These consistent patterns in speech errors reveal the existence of an organizational framework for the syllable into slots or frames that are totally independent of the segments that can occupy these slots in phonologically appropriate orderings. The constraints on speech errors are strictly controlled by the structure of the syllable.

It appears then that language users possess a representational distinction between phonemes and syllables. It is interesting to note that speech errors appear to be quite rare, if they occur at all, in young children. The fact that the normal children in this study were able to intuitively organize and represent syllabic constructs, however, shows that the linguistic distinction is already neurally encoded. The same cannot be said for the DAS children.

A second line of behavioral evidence showing interaction effects between syllabic structure and phonetic output is analysis of pronunciation errors in second language learning (Broselow, 1983, 1984). For example, Egyptian Arabic speakers learning English insert the vowel [i] between C1 and C2 clusters and say ''filoor'' for ''floor,'' as Arabic does not allow syllable initial consonantal clusters. Other examples are seen when English speakers try to pronounce foreign words that begin with a nasal-consonant cluster, such as the African names ''Nkomo'' or ''Nkrumah.'' This construction violates English syllable phonotactics and speakers modify the cluster to conform to permissible syllable organization. Thus,

[nkomo] becomes [enkomo] and [nkrumə] becomes [nɪkrumə]. Other commonly seen examples occur when consonant order is changed to, once again, conform to native language syllable constraints. In producing the name of the one-time Iranian politician ''Ghotbzade,'' one often heard [gatzbade]. Since an English syllable cannot end in ''tb'' or begin with ''bz,'' the Iranian cluster does not permit division into permissible syllables. By reversing the order of the ''bz'' consonantal cluster to ''zb,'' English speakers transformed the impermissible cluster into an initial syllable ending in the permitted postvocalic cluster ''tz.'' These compensatory articulations are attempts to bring native language syllable structure to foreign forms. The underlying syllabic structure, which is viewed as an independent neurally based entity, can be seen to exert a very powerful transfer effect on a speaker's output. Obviously, the same powerful effect that causes mispronunciations in learning a second language can exert a similar controlling effect within production of the native language. The inviolate nature of a language's phonotactic constraints illustrates this notion; the inherent ''tongue twisting'' nature of phonotactics gone awry (e.g., /sd/, /gt/, /dl/ initial clusters) indicates a degree of 'hardwiring' in these syllabic-based representations. These common examples illustrate our claim that syllabic frameworks can and do influence output errors that appear, on the surface, to reflect only motor sequencing errors for segments.

In DAS, the sequence of individual phonetic segments may not be constrained by any well-formed, functionally operational, syllabic framework. Their output string may lack ''placeholders'' for juxtapositioning consonants and vowels. As stated by MacNeilage and Davis (1990), the syllable ''serves as a structured repository controlling the serial position of individual segments'' (p. 56). It is certainly possible that language substrates can be adversely affected in neurodevelopment such that the neural instantiation of these ''structured repositories'' fails to develop in a normal fashion. Predicted speech motor characteristics of such a disorder would certainly include restricted phonemic repertoires, inconsistent phonemic errors, difficulty in sequencing speech movements, and delayed expressive language.

Suprasegmental elements should also be severely compromised in DAS as the syllable is often regarded as ''the interface between the segmental and the suprasegmental levels of speech production'' (MacNeilage & Davis, 1990, p. 56). Intonation contour, stress, and the entire rhythmic organization of speech output would be expected to suffer if an impoverished syllabic structure existed. ''Successful'' output in such a phonologically limited situation would consist, perhaps, of holistic, highly familiar, lexical entities similar to right hemisphere recognition capabilities (Zaidel & Peters, 1981), rather than sound sequences neurally programmed by a language system working with a finite set of phonemic elements in conjunction with an organizational syllabic frame. Future studies of DAS will systematically investigate the perceptual integrity of their input system. DAS children should be severely compromised in basic sensory perception of phonemic contrasts compared to age-matched children.

Appendix A

A.1. Task I: syllable awareness

One-syllable	Two-syllable	Three-syllable	Four-syllable
bee	mistake	telephone	European
dirt	window	animal	automobile
ant	peanut	grocery	television
throw	battle	elephant	sensational
book	picture	gasoline	aquarium
burn	chicken	computer	secretary
hike	morning	hamburger	accordion
brush	garden	radical	alligator
out	upset	envelope	entertainment
red	father	area	hyperactive

A.2. Task II: intrasyllabic position

Prevocalic	Vocalic	Postvocalic
game–name	bet–bat	fan–fat
her–fur	kit–cat	mop–mob
pan–can	said–sad	jam–jazz
fish–wish	cub–cab	lose–loop
boat–coat	fat–fit	hot–hop
rot–cot	moon–man	save–same
nut–rut	ton–tan	gaze–gate
feet–meet	did–dad	nice–night
last–past	shop–sheep	rest–wreck
soon–moon	mess–mass	mood–moose

A.3. Task III: intrasyllabic structure

CV	VC	CVC	CCV	CCVC	CVCC	CCCVC
low	on	kiss	blue	track	post	scrub
knee	eat	fan	free	plate	tilt	strum
tea	am	boat	cry	flute	cost	stream
key	ate	can	clue	spin	most	scream
bow	are	bat	spa	blood	camp	split
know	oat	moose	glee	from	limp	strap
way	air	tin	snow	spoon	colt	scrape
tow	it	cot	flow	flat	band	strip

Appendix B. Continuing education questions

1. Syllables:
   (a) are a fundamental constituent in phonological theory.
   (b) are relatively easy to define in unambiguous terms.
   (c) can be used to study directly the mental representation of phonological structures.
   (d) are not related to suprasegmental aspects of speech production.
2. This study found that participants with DAS had difficulty with:
   (a) identification of the number of syllables in a word.
   (b) judging the position of sounds within syllables.
   (c) constructing syllable shapes within monosyllable frames.
   (d) all of the above.
   (e) none of the above.
3. According to this study, the relationship of syllable level performance and therapeutic intervention is:
   (a) syllable-level deficits are present due to lack of intervention.
   (b) syllable-level deficits are present due to inappropriate focus of intervention.
   (c) syllable-level deficits persist despite appropriate therapeutic intervention.
   (d) children with DAS do not demonstrate syllable level impairment.
4. Variability of task performance between DAS participants suggests that those with fewer syllable errors:
   (a) have a less severe form of the disorder.
   (b) were incorrectly diagnosed with DAS.
   (c) demonstrated associated language comprehension deficits.
   (d) received less treatment.
5. Based on this study, the authors argue that DAS is best characterized as:
   (a) an articulation-based motor control deficit.
   (b) a disorder characterized by an impoverished representation system for phonological constructs.
   (c) a neuromuscular speech disorder.
   (d) a language disorder characterized by a high incidence of grammatical errors.

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